Preface: Disaster Response and Management

To say that disasters are complex is somewhat of an understatement. They create situations that are often chaotic in nature and drive normal human and infrastructure response beyond their usual operational limits. The characteristics of the well-known stages of disaster, which include planning, response, recovery, and prevention, hide the underlying complex challenges of applying normal services such as policing, health care, infrastructure management, and similar daily activities to disasters.

The profound needs following disasters often exceed available resources and connect the demands of those resources in an unexpected manner. For example, an emergency service accustomed to dealing with an influx of patients in a hospital now has to determine how to move all of those patients from that location due to flooding. Or, transport that ordinarily delivers needed supplies to destinations cannot operate because operators themselves cannot report to duty and roads are blocked. Incidents that rob populations of their habitat, triggered by planet-driven events or by human conflict, create mass migrations, which in turn impact neighboring regions and cause social disruptions.

This issue of the *IBM Journal of Research and Development* is focused on disaster management and has assembled a number of articles that attempt to explain the scope and complexity of the domain. Articles range across topics, from a view of how corporations actually respond to and help with disasters, to models of how NGOs interact and impact the logistics of response. This issue includes articles that describe how hackathons focused on disaster-related technologies are deployed, and how monitoring of workspaces and the elderly during disasters helps save lives. The use of artificial intelligence (AI) and computation as applied to such varied domains as refugee management, highly localized weather prediction, and climatic effects add to the scope and range of this issue. Rather than focus on just technology, the issue also includes efforts to characterize attempts to affect human behavior in preparing for disasters. Clearly, it is impossible to cover even a small subsection of disaster response technologies and approaches in a single publication, but as guest editors, we have tried to provide a sampling of the range of research in this very broadly framed domain.

The issue is led by a concise article from Talley, who provides a succinct overview describing the nature of disasters, their conflicting demands, the human- and machine-based responses, and the manner in which relatively new approaches such as big data, blockchain, and AI have served to help manage the chaos that often follows these events.

It is followed by an article by Curzon et al. that provides detailed insights into how the IBM Corporation has responded to help populations in peril over the last two decades. The article describes the evolution of this response, driven by the influence of the company's business directions and capabilities. It also demonstrates how a clear strategy based on the placement of personnel around the world whose responsibilities are to establish local relationships with NGOs and governments is a strategic asset. It demonstrates with specific examples how these trust-based relationships are vital to the implementation of immediate and effective actions in preparing for and dealing with disasters.

Baxter et al. provide a rich review of disaster response from the standpoint of models that describe the planning and response associated with disasters. Their focus on the methodological aspects of disaster response is categorized through three lenses: prepositioning of resource, resource allocation and delivery, and network restoration. The latter refers to infrastructure networks such as utilities or transportation and services, and determines where and in which sequence to repair these broken systems under a variety of constraints.

It is unlikely that the article by Malaika et al. would have been published a decade ago since the concepts of collaborative development of disaster solutions at a global level were unlikely with the capabilities and the communities of that time. Similarly, the passion and abilities of developers probably existed, but the abilities to make them visible and mobilize them around the issues of disaster response and management did not exist. The authors provide a unique insight into the organization of such events, the technical resource necessary to deploy them, and the global networks that need to be deployed to create a successful result.

The following section of the journal focuses on the deployment of a variety of big data and AI technologies and includes an article by Albrecht et al. describing an IBM petabyte-based approach to geographic information systems (GIS) called PAIRS, which provides an online analytical service for a very broad range of GIS-based data located in its repository, including real-time data. In the context of disaster management, PAIRS allows users to leverage this GIS data to determine the effects of storms, earthquakes, and other events on the geographic area of interest. The article also describes how the growth of multiterabyte-per-day data generation is forcing the migration of data management techniques that relied on relational databases with spatial extenders to HADOOP-based filesystems integrated with NoSQL datastores and shows how these techniques have been applied to earthquakes and fires.

Treinish et al. describe the creation and use of advanced, very high-resolution, city-block-scale weather forecasting, named Deep Thunder, and how it can be extended to climate-scale modeling, both of which clearly significantly

---

Digital Object Identifier: 10.1147/JRD.2020.2966837

impact disasters. Deep Thunder has been used to help utilities predict outages and their locations, flooding, and even urban heat islands. More recently, these weather predictions have been combined with the Pseudo-Global Warming method to use the predicted effects of global warming on the micro-scale weather to help coastal cities, where most of the world's population[1] lives, or to decide on weather mitigation approaches.

Nair et al. take an interesting AI-based approach to predict the annual migration of refugees across the globe. Using freely open data, they constructed a macro model based on institutional data (e.g., GDP differences between countries) from such providers as the World Bank and the UN Refugee Agency and integrated it with traditional metrics such as migration numbers. The model was developed around six specific migration routes from Ethiopia and provides an annual migration prediction number to those specific endpoints. Mean absolute percentage errors were estimated to be of the order of 20%–30%. They found correlation between the exogenous parameters such as socio-demographic effects on that migration. They also discuss the challenges in extracting causality from a pure machine learning approach.

Along similar lines, Enenkel et al. decided to use remote sensing data to observe changes in Night Time Lights related to displacement, using the National Aeronautics and Space Administration satellite system and their product suite called Black Marble. The article claims to be the first attempt to use this information and deploy Black Marble for humanitarian analysis. Using Black Marble and SMS messaging, the authors were able to analyze the effects that tropical cyclone Idai had on internal displacement in Mozambique.

Kreutzer et al. focus their attention on the feasibility of the use of natural language processing (NLP) to interpret data acquired by humanitarian organizations to better understand and quantify responses and gain situational awareness from people suffering from disasters. The use of computer-assisted telephone interviewing and computer-assisted personal interviewing is discussed. The article also delves into the ethical issues of acquiring data from people who may feel that they must provide that information in order to receive relief from their perilous situations.

Murakami et al. show the use of NLP processing of text, specifically analysis of Twitter data, from the Kumamoto Earthquake (in 2016). The use of location data from the Twitter stream provided additional context and allowed NGOs to optimize response logistics and assign resources such as food and water in a more effective manner.
The availability of some 800 million Twitter messages from the region around the quake, gathered over three months, proved to be a trove of useful information and demonstrated the value of this analysis.

Allen et al. present an article that analyzes the manner in which communications and warnings about impending disasters are perceived and acted upon. Initially, it would seem that this would be a simple exercise, but communication science indicates that the situation is more complex and that it is important to deal with three issues: the value of the communications as perceived by the recipient; the barrier to understanding the information; and the request made of the recipient. The authors create a psychological model of risk communication and refine it by interviewing individuals about extreme heat events and floods. They conclude that although people understand the extreme challenges associated with these events, they lack clarity in planning to deal with them.

Nagurney et al. have developed a supply chain-based model framework that helps quantify the value of synergetic collaboration between agencies or NGOs dealing with disasters, focusing attention on the supply chains of the individual groups. Importantly, these models capture the uncertainties associated with costs and demands in these chains and propose metrics that assess the potential strategic advantages of cooperation among humanitarian organizations. By creating a number of numerical examples, they demonstrate the benefit from this cooperation accrued by people in peril who therefore receive more relief products in a more cost-efficient way. Finally, the model and the measure provided in the article can also elicit meaningful guidance to NGOs in terms of planning.

Shiri et al. take another perspective of the supply chain and consider the challenges of delivering relief material to locations impeded by blocked roads. The authors provide a review of this problem, which is a significant challenge to emergency response teams. Using a set of heuristics, they develop approaches to affected communities that optimize delivery of rescue assets. This challenge, often called the Canadian Traveler Problem, is tested on realistic city road systems as well as synthetic routes that have been randomly generated. They compare two solutions, one which has the complete known list of blockages and the other where blockages are discovered piecewise, which is the usual situation during disasters.

Dalal et al. create a framework they term a Risk Analysts' Workbench, which utilizes machine learning to analyze data from millions of past workplace insurance claims that then help identify hazards that resulted in those claims. Using real-time video and other monitors, they show how the learning from these claims can be mapped to this real-time data and can help predict hazards in the workplace that in turn can result in new claims. It is thus possible to map these kinds of analytics to many situations including disasters where some level of real-time data may be

---

[1] https://www.worldbank.org/en/topic/urbandevelopment/overview

available. The creation of risk maps from these analyses yields useful insights and can help responders in their activities avoid hazards that can be compounded from multiple sources. An example might include fire personnel fighting fires in forests where, with sufficient training data, responders could be efficiently directed to minimize their peril and maximize their effectiveness.

Continuing in the vein of applying AI to disaster-related analysis and prediction, Litoriya et al. address the issue of helping the very vulnerable population of the elderly during disasters. They start with a review of the literature involving IoT-based disaster monitoring and providing insight on the significant differences between the mature and evolving economies. In their research, they monitor the frequency and timing of the opening by elderly residents of three different doors in their home, specifically the main door, the refrigerator door, and the bathroom door. Monitoring these simple metrics, they note any discrepancies in behavior that could demonstrate abnormal patterns of use by the elderly residents. They then combine information from two sources, one being the behavior acquired from the door activity, and the second including disaster warnings and information in a given region. Any changes derived from this synthesis are reported to disaster response agencies.

Klima et al. complete the issue with an article that takes the current Federal Emergency Management Agency flood maps and combines that information with a derived water vulnerability risk to derive a “water vulnerability index,” which includes some 11 factors, many of which are census-related. They also looked at the costs of moving populations from these vulnerable regions by buying them out, versus elevating the existing infrastructure, and they find relatively little difference between them. Their novel approach was somewhat limited by the range of data they were able to acquire, but their methodology provides a sound basis for getting real insight about the challenges and costs of taking an action, which goes far beyond the use of simple flood maps.

Jurij Paraszczak
IBM Corporate Citizenship

Rebecca Curzon
IBM Corporate Social Responsibility

Seshadri Subbanna
IBM T. J. Watson Research Center

Hendrik Hamann
IBM T. J. Watson Research Center

Guest Editors